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THE LEAF HOPPERS ATTACKING APPLE IN THE OZARKS[1]

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The Bureau of Entomology in Cooperation with the Arkansas Agricultural Experiment Station

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INTRODUCTION

Injury to the foliage of apple trees is often the cause of heavy loss in fruit production. Among the common insects which attack apple foliage in various regions are the leaf hoppers. These cause serious

[1] These studies were carried on at Bentonville, Ark., under the direction of A. L. Quaintance, at that time Associate Chief of the bureau, in charge of the Division of Deciduous Fruit Insects, Bureau of Entomology. The work was conducted at intervals from 1918 to 1929. E. W. Cook, temporary field assistant, aided in the rearing work from 1925 to 1929. Determinations of leaf hoppers were made by W. L. McAtee, of the Bureau of Biological Survey. Determinations of natural enemies were made by W. L. McAtee and S. A. Rohwer. To all these the writers express their appreciation for assistance in this work.

[2] Formerly with the Bureau of Entomology, U. S. Department of Agriculture; resigned September, 1921.

foliage injury during many seasons, especially in the Ozark district of northwestern Arkansas.

Growers are less familiar with leaf hoppers and the injury they produce than they are with the pests that directly attack the fruit. Leaf hoppers injure the leaves by sucking the plant juices and frequently discolor the fruit by their excrement.

This bulletin deals with the biology, habits, and control of the five species of leaf hoppers which attack apple in the Ozarks.

SPECIES OCCURRING IN THE OZARKS, THEIR COMMON NAMES, AND RELATIVE IMPORTANCE

There has been much confusion concerning the identity, the names, and the habits of the various species of leaf hoppers which attack

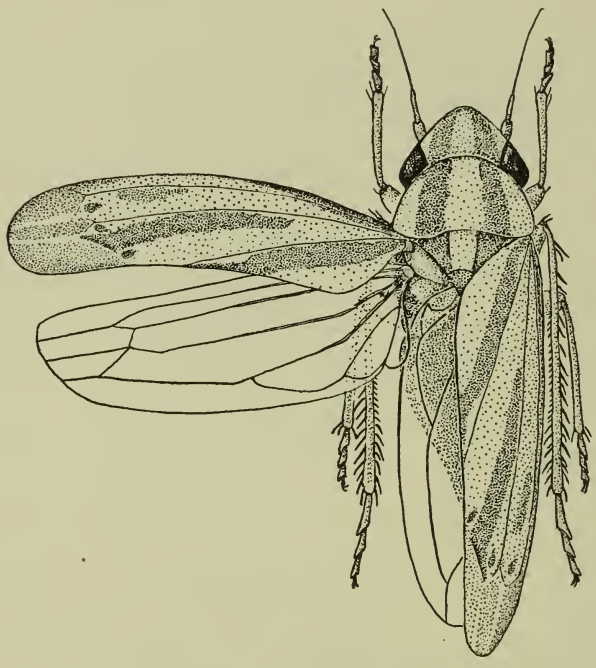

FIGURE 1.—The oblique-striped apple leaf hopper (*Erythroneura obliqua*). × 25

apples throughout the United States. In American entomological literature injury by apple leaf hoppers has been attributed for the most part to three species, *Empoasca fabae* (Harris), *E. maligna* (Walsh), and *Typhlocyba rosae* (L.). The two most important leaf-hopper pests of apple in the Ozarks, as well as in some other fruit districts, have received no attention hitherto, except from the systematic point of view, though these two species, *Erythroneura obliqua* (Say) and *E. maculata* (Gill.), unquestionably have been apple pests for many years. Furthermore, *Typhlocyba rosae*, a pest of rose, has been confused heretofore with another species, *T. pomaria* McAtee, which is essentially a pest of apple.

Graphocephala coccinea (Forst.) may be found breeding on apple, but the preferred host plants of this species are grasses and weeds. It was quite abundant on weeds in the insectary yard at Bentonville, Ark., in 1925, and some individuals reproduced on near-by apple trees.

The leaf hoppers which cause injury to apple in the Ozarks, in the order of their importance, are *Erythroneura obliqua* (Say) (fig. 1), *E. maculata* (Gill.) (fig. 2), *Typhlocyba pomaria* McAtee (fig. 3), *Empoasca fabae* (Harris) (fig. 4), and *E. maligna* (Walsh) (fig. 5).

Erythroneura obliqua was termed the "oblique-striped Erythroneura" by Fitch (*15, p. 63*)[3] in 1851. This is the only common name which has been applied to this leaf hopper. Since apple is its preferred host plant this species may be appropriately called "the oblique-striped apple leaf hopper."

No common name has been applied to *Erythroneura maculata*. It is suggested that this species be named "the red-spotted apple leaf hopper" because of the characteristic color markings of the insect.

Typhlocyba pomaria also has no common name. It is proposed that this insect be called "the white apple leaf hopper," the name being based on the general color of the insect.

The green-colored leaf hopper *Empoasca fabae* has been termed "the potato leaf hopper" by Ball (*3, p. 152*), and as this species is primarily a potato pest, this name is considered appropriate.

FIGURE 2.—The red-spotted apple leaf hopper (*Erythroneura maculata*). × 20

Ball (*4, p. 597*) named *Empoasca maligna* "the apple leaf hopper" because "it spends its whole life on the tree and frequently does serious injury." This is the least injurious of the leaf hoppers attacking apple, however, so the name is inappropriate for the species. *E. maligna* will be designated "the green apple leaf hopper" in this bulletin.

The two species of Erythroneura (*E. maculata* and *E. obliqua*) are by far the most injurious of the apple leaf hoppers in the Ozarks. Of these *obliqua* is probably the more abundant. The relative importance of the two species, however, is exceedingly variable from one orchard to the next and from one season to another. They are usually associated in the same orchards, seem to thrive under similar conditions, and have almost identical seasonal histories. These species are

[3] Italic numbers in parentheses refer to Literature Cited, p. 38.

similar in appearance, both being marked with red or orange red upon a white background when viewed from above. They can be distinguished easily, however, as the wings of *obliqua* have two distinct oblique red lines, whereas the wings of *maculata* are marked with irregular red spots.

The long, dry, hot seasons which are common in the Ozarks are evidently favorable for these two species. They have never been observed to be harmed by extremely high temperatures as have the other species. Nymphs and adults of both species are present on apple throughout the entire growing season.

FIGURE 3.—The white apple leaf hopper (*Typhlocyba pomaria*). × 25

The white apple leaf hopper, *Typhlocyba pomaria*, was the most important species in 1918. Since 1919 it has hardly been a pest in the Ozarks, probably owing to parasites or adverse climatic conditions. It is, however, the most injurious of the apple leaf hoppers in the northern fruit sections. In the Ozarks hot weather often produces a high mortality of both nymphs and adults of this species. This fact was observed in September, 1925, when second-generation nymphs and adults were killed by thousands by temperatures of about 100° F. for several successive days.

The incubation period of summer eggs of the white apple leaf hopper in Arkansas ranges from 63 to 86 days, and neither nymphs nor adults are present in orchards from the middle of June to the

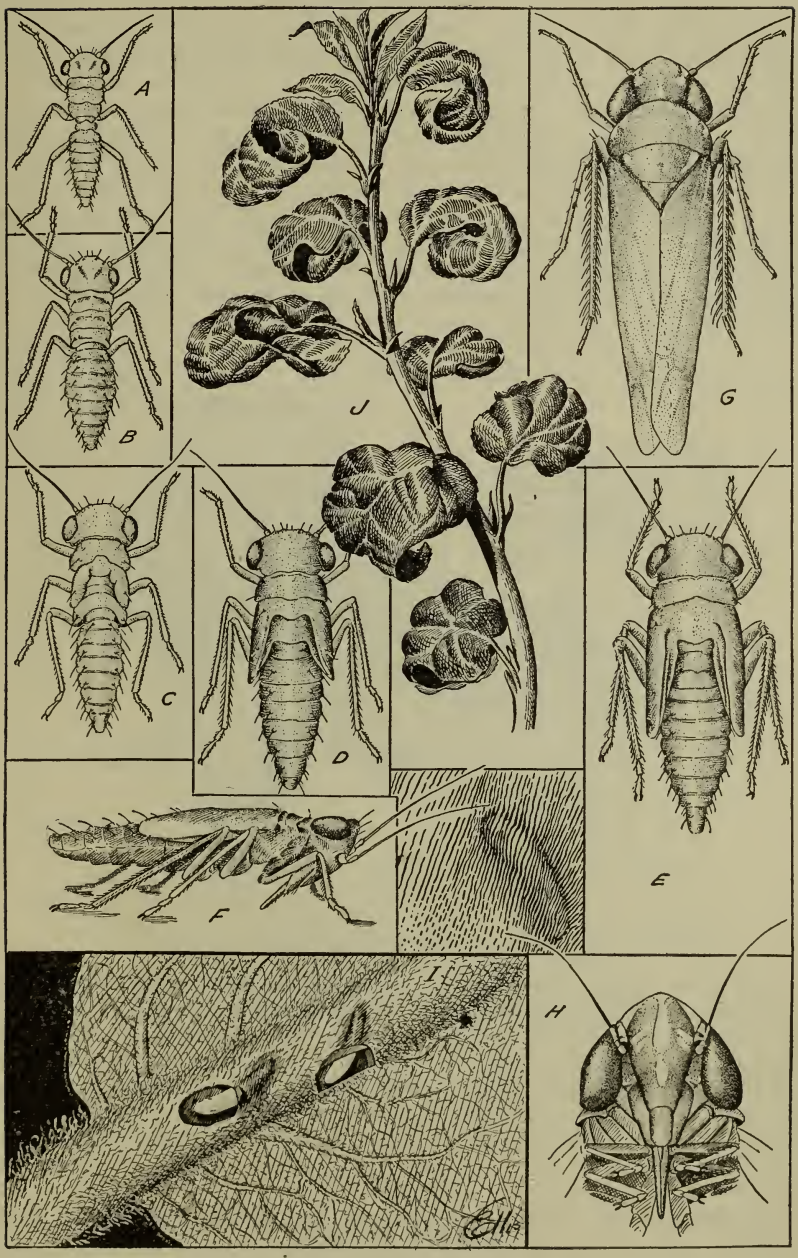

FIGURE 4.—The potato leaf hopper (*Empoasca fabae*): *A*, First nymphal stage; *B*, second stage; *C*, third stage; *D*, fourth stage; *E*, Fifth stage; *F*, side view of the fifth stage; *G*, adult × 17; *H*, front view of head of adult; *I*, eggs in tissue on underside of apple leaf; *J*, curled condition of terminal leaves of apple due to attack by the potato leaf hopper

latter part of July. The active stages of the insects, therefore, usually escape exposure to high temperatures.

The potato leaf hopper, *Empoasca fabae*, is a serious pest in the potato sections of Iowa, Minnesota, and Wisconsin, but in the Ozarks damage to potatoes by this leaf hopper is usually of little consequence. In 1925 temperatures of over 90° F. caused considerable mortality of both nymphs and adults. This was quite a factor in reducing the abundance of the species after the middle of June, by which date the first generation was completed. It is frequently a pest of young apple trees, though in some seasons the first generation causes injury to terminal foliage in bearing orchards. This leaf hopper has never been observed to be injurious enough on bearing apple trees in the Ozarks to require a spray for its control.

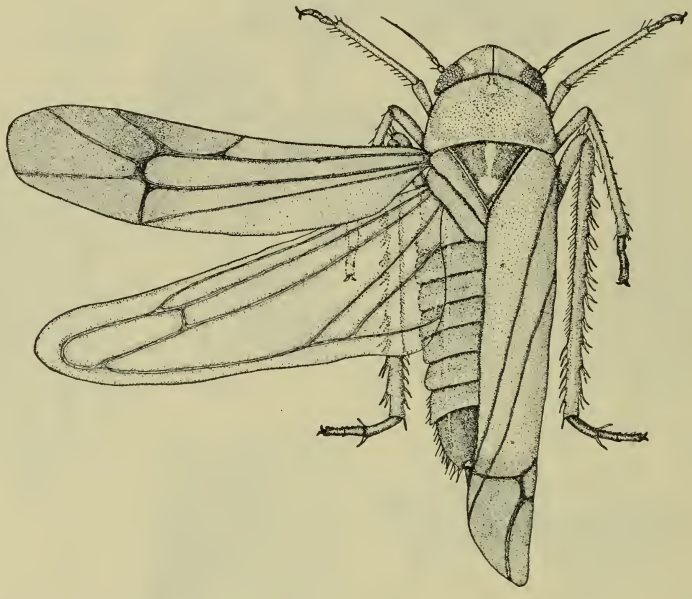

FIGURE 5.—The green apple leaf hopper (*Empoasca maligna*). × 20

The green apple leaf hopper, *E. maligna*, has been reported as a true pest of apple in western New York by Lathrop (*23, p. 185*). In the Ozarks, however, this leaf hopper will probably never become abundant enough to be rated as a pest of apple. It is usually found only on young trees. This species has one brood annually, and feeding takes place during a period of only about three months during the early summer. Injury by this species is relatively unimportant.

OTHER SPECIES INFESTING APPLE IN OTHER PARTS OF THE UNITED STATES

Erythroneura hartii Gill. (fig. 6) is a species of economic importance on apple in the localities where it occurs. This leaf hopper has not been found west of the Mississippi River. It is one of the

injurious leaf hoppers, however, in Illinois and Indiana. It is generally distributed from Illinois to Virginia. Stearns (*37*) has described the work of this leaf hopper as a pest of apple in Virginia.

The rose leaf hopper, *Typhlocyba rosae* (L.), is essentially a pest of roses, but it also attacks apple occasionally. The species has been confused with *T. pomaria* McAtee frequently, but its distribution apparently covers the northern half of the country. It has not been collected in Arkansas during the course of these studies. In 1927 Lathrop (*24*) published a report of the injury caused by these two species of Typhlocyba on apple in New York.

A new species (*Typhlocyba*) *Empoa malini* DeLong, was described from Ohio by DeLong (*12*) in 1926. This leaf hopper was said to resemble *rosae* very closely. McAtee (*32*), after examining specimens of *malini*, found it to be *Typhlocyba xanthippe* McAtee, the latter name having priority because of earlier publication.

Idiocerus provancheri Van Duzee attacks apple occasionally in northern fruit sections.

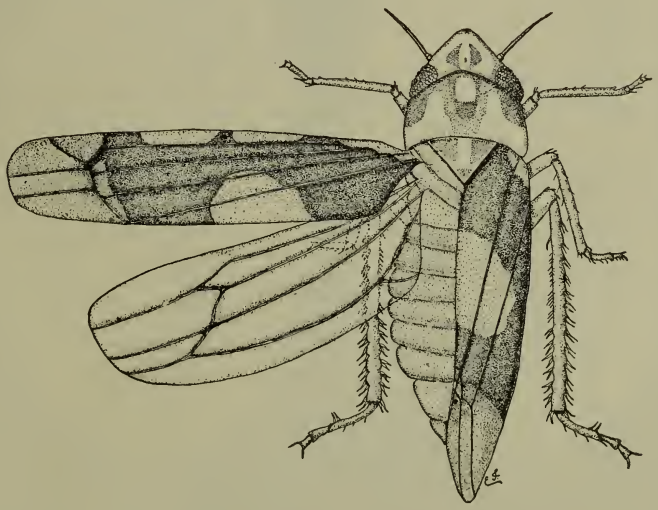

FIGURE 6.—*Erythroneura hartii.* × 25

COMPARISON, AS TO LOSSES, WITH OTHER APPLE PESTS

Leaf hoppers as pests of apple in the Ozarks are of secondary importance, and the losses which they cause can not be compared with the injury caused by the codling moth or San Jose scale. Of the second-rate pests, they are the most widely distributed and most regular in their appearance year after year; this is especially true of the two species of Erythroneura. Injury to apple by the plum curculio is more severe in a few orchards, but appreciable injury by the curculio during the last few years has not been general and, as a whole, is of less consequence than leaf-hopper injury. The various species of borers are also of local occurrence. In bearing orchards that are regularly sprayed for codling-moth control leaf-feeding caterpillars are of little consequence.

CHARACTER OF INJURY

The nymphs and adults of the species of leaf hoppers concerned, except *Empoasca fabae*, feed almost entirely on older leaves and usually in the lower parts of trees. They never attack growing leaves on the terminals. They congregate on the lower surfaces of the foliage, pierce the leaf tissue with their tiny beaks, and suck the plant juices. The injured leaves lose chlorophyll in spots (fig. 7), and when the attack first begins the leaves present a mottled appear-

FIGURE 7.—Typical injury to apple leaves caused by all species except the potato leaf hopper

ance. As the injury continues the leaves lose most of the green color and become grayish green above. More or less extensive defoliation may follow.

When leaf hoppers are very abundant late in the season, they may cause minor injury to fruit by preventing proper coloring. If nymphs are very abundant in September the upper surfaces of all fruit in the lower part of the trees may be covered with excrement, which is attacked by a black fungus. The parts of the fruit thus covered fail to color and present an unsightly appearance.

The injury to foliage and fruit through the covering of the upper surfaces with excrement is direct and easily established. It is probable that the indirect injury is greater, although it is not so easily

determined. During dry seasons leaf hoppers are charged with increasing the premature dropping of fruit in late August and in September. Such seasons are usually favorable to leaf-hopper development. Unfortunately it is during a dry season that trees are less able to resist a heavy drain of sap.

Empirical observations indicate that leaf-hopper injury to foliage delays coloring of such varieties as Arkansas (Mammoth Black Twig) and Ben Davis and otherwise reduces quality. Leaf-hopper excrement on Jonathan and Grimes Golden often interferes with the finish of these varieties.

In addition to the injury that they cause, adult leaf hoppers are a source of much annoyance to apple pickers. This is especially true during hot, dry seasons when adults become so numerous by late summer that they actually arise from the foliage in clouds, when disturbed, and cause considerable discomfort by swarming into the eyes and ears of persons engaged in harvesting the crop.

The injury caused by the potato leaf hopper (fig. 4) is quite distinct from that just described. This leaf hopper attacks the terminals exclusively, causing curling of the leaves and checking of the young growth. When the insects are abundant on apple the infested terminal leaves present a burned appearance at the tips and along the margins. This type of injury on potato has been termed "hopperburn" by Ball (*3, p. 149*). This leaf hopper is a destructive pest of potatoes, but it also causes serious injury to beans, apple nursery stock, alfalfa, clovers, and several other plants in some localities.

CHARACTERS FOR DISTINGUISHING THE SPECIES

There are two distinct color forms of each of the two species of Erythroneura, a red form and a yellow or pale form. In the typical red form the color markings are orange red; in the yellow form the patterns are the same as in the red form, but the color markings range from yellow through light greenish yellow to pellucid. Individuals of the yellow or pale form of both species are more abundant than those of the red form during most of the season. Red individuals predominate only during the cool weather of late fall and winter.

A distinct variety, *Erythroneura obliqua* var. *dorsalis* (Gill.)[4] (fig 8), is also common in practically all orchards. This variety differs from the typical *obliqua* by the red stripes being so broadened and run together as to form a continuous red or dark dorsal stripe the entire length of the insect.

Variety *dorsalis* is always associated with the typical *obliqua* in orchards, and they copulate without discrimination. In cage studies in 1920 and 1921 it was found that the typical *obliqua* and *dorsalis* interbreed to such an extent that mated pairs of either form frequently produce offspring with the other type of color pattern.

In the cage experiment of 1921 a number of pairs of the overwintering generation of *dorsalis*, taken in coitu, were placed in a cage over a tree which had been previously protected from infestation for about two weeks. No typical specimens of *obliqua* were included.

[4] The name *Erythroncura lawsoniana* was proposed for this leaf hopper by Baker in 1926 (*2*).

Of 50 offspring of these mated pairs of *dorsalis* reared in the tree cage, 46 had the *dorsalis* coloration. Four were typical *obliqua*. Another tree cage was used exclusively for mated pairs of the typical *obliqua*. Only 28 nymphs from this cage were brought to maturity. Of this number, 23 were of the typical red form, 4 were pale form *obliqua*, and 1 was *dorsalis*.

The following key will serve to separate the adult leaf hoppers:

A. General color, viewed from above, green.
  B. Adults deep green, robust, with a blunt vertex---------- *Empoasca maligna*.
  BB. Adults pale green, slender, with a rather pointed vertex---------- *Empoasca fabae*.
AA. General color, viewed from above, creamy white-- *Typhlocyba pomaria*.
AAA. General color, viewed from above, white with red or yellow stripes.
  B. Wings with one distinct red oblique stripe---------- *Erythroneura obliqua* var. *dorsalis*.
  BB. Wings with two distinct oblique stripes.
    C. Oblique stripes red-- *Erythroneura obliqua* (red form).
    CC. Oblique stripes yellow---------- *Erythroneura obliqua* (yellow form).
AAAA. General color, viewed from above, white with irregular red or yellow spots.
  B. Spots red---------- *Erythroneura maculata* (red form).
  BB. Spots yellow---------- *Erythroneura maculata* (yellow form).

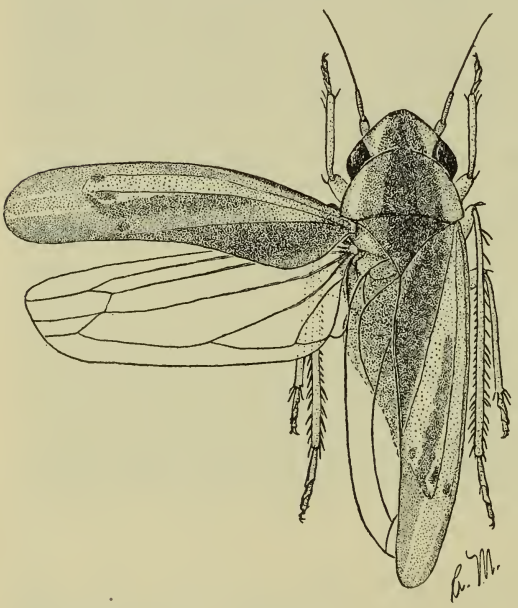

FIGURE 8.—*Erythroneura obliqua* var. *dorsalis*. × 25

Nymphs of the different species may be readily separated by their color, by their feeding habits, and by the time of appearance of the first generation on apple.

Nymphs of *Typhlocyba pomaria* are white, they infest only the lower leaves, and are the first species to appear on apple. Hatching begins about the time the "petal-fall" spray is due.

Nymphs of *Empoasca maligna* are green, they feed on the lower leaves, and hatching begins a few days later than the hatching of the preceding species.

The yellowish-green nymphs of *E. fabae* attack the terminal leaves, and their first appearance on apple is about a month later than that of *maligna* nymphs.

The nymphs of *Erythroneura obliqua* are white with dark spots on the dorsal side of the thorax. These nymphs feed on the lower leaves and hatching starts several weeks later than that of *fabae*.

Nymphs of *E. maculata* hatch at the same time as those of *obliqua*, and they also feed on the lower leaves. They differ from *obliqua* by lacking the dark markings of that species.

The ground color of the variety *dorsalis* is yellow in the nymphal stages, instead of white as in the typical *obliqua*. The red and the yellow color forms of the two species of Erythroneura can not be distinguished in their immature stages.

Nymphs of the different species are easily distinguished from one another by the characters given in the following key:

A. Nymphs green.
  B. Nymphs bright green, robust, infesting lower leaves_ *E. maligna.*
  BB. Nymphs pale green, slender, infesting terminal leaves_ *E. fabae.*
AA. Nymphs white or cream colored, usually present on foliage of lower limbs.
  B. Dorsal area of vertex and thorax marked with dark spots _____ *E. obliqua.*
  BB. Vertex and thorax without dark spots.
    C. Vertex flattened in front_____ *T. pomaria.*
    CC. Vertex angular in front_____ *E. maculata.*

THE OBLIQUE-STRIPED APPLE LEAF HOPPER [5]

HISTORY AND SYNONYMY

The oblique-striped apple leaf hopper was originally described by Say (*36, p. 342*) in 1825 as *Tettigonia obliqua.* In 1851 the genus Erythroneura was erected by Fitch (*15, p. 62*) to include, among other species, *T. obliqua* Say. Fitch applied the first common name to the insect at this time when he called it "the oblique-striped Erythroneura." In 1856 Fitch (*16, p. 435*) mentioned this species as attacking wild currant and various other shrubs and trees; he also observed adults under leaves in winter and noted variations in the coloration of specimens.

Erythroneura obliqua has been referred to frequently in literature under the genus Typhlocyba, by Woodworth (*45*), Van Duzee (*39, p. 201*), *Gillette* (*21, p. 756*), Osborn (*34, p. 545*), and others. The earliest mention of the insect as a pest of apple was by Quaintance as reported by Lyon (*27*) in 1915. This species was placed in the genus Erythroneura by Van Duzee (*40, p. 714*). McAtee (*29, p. 277*), 1920, redescribed the typical red form as *Erythroneura obliqua* var. *obliqua* (Say). In 1930 Beamer (*6, p. 417–456*) divided *Erythroneura obliqua* into 64 species and varieties following a study of the genitalia of the insects. Specimens of the oblique-striped apple leaf hopper have been identified as one of the new species, *E. magnacalyx* Beamer. The name *E. obliqua* is retained, however, for this apple leaf hopper. No published account of the biology of the oblique-striped apple leaf hopper has appeared heretofore.

DISTRIBUTION AND FOOD PLANTS

The oblique-striped apple leaf hopper is undoubtedly a native species. McAtee (*29, p. 275*) gives its known range as extending from Quebec, Ontario, and Colorado to Virginia, Louisiana, and possibly California. It is especially abundant in apple orchard sections of the Central West from Kansas to Indiana.

Much uncertainity exists in published records with respect to the food plants of this leaf hopper. Gillette (*21, p. 757*) states that "this is one of the grape-infesting species and is commonly taken

[5] *Erythroneura obliqua* var. *obliqua* (Say); order Hemiptera, family Cicadellidae, subfamily Eupteryginae.

along with *comes* and its varieties." This is undoubtedly an error, for the insect does not reproduce on grape. In the insectary yard at Bentonville, Ark., for instance, a row of bearing grapevines is flanked on both sides by apple trees, and all plants are so closely crowded that the grapevine and apple tree touch one another; yet in this yard *E. obliqua* infests apple throughout the season, but does not attack the grape foliage close at hand. The grapevines are infested with several species of grape leaf hopper, and these species likewise confine their attack to their favored host plant and do not stray to apple.

It is probable that this species was a pest of Crataegus and other native forest trees and that it has adapted itself to apple in recent years. This assumption is borne out by the fact that the insect was present in the country almost a hundred years before apple was mentioned as a host plant. Though the insect breeds to a limited extent on some shrubs and forest trees, apple is the only host plant upon which it is now known to be a pest.

DESCRIPTION OF THE STAGES OF ERYTHRONEURA OBLIQUA

During their life history leaf hoppers pass through the following stages: The egg; the nymph; and the adult, or mature insect. The nymphs resemble the adults in a general way, the most striking difference being that they are wingless. Between hatching and transformation to adult the nymphs molt five times, so there are five nymphal instars. All the stages of one of the leaf hoppers attacking apple, *Empoasca fabae*, are shown in Figure 4.

A description of the stages of *Erythroneura obliqua* follows:

THE EGG

Egg elongate, bean-shaped, slightly smaller at one end than at the other. Almost transparent when first deposited, changing to pale white. Average length 0.7 mm., average diameter 0.25 mm.

THE NYMPH

First instar.—General color light yellow after feeding. Eyes deep red. Antennae extending to hind margin of thorax. A dark irregular line apparent along the frontal margin of the vertex and also one near each lateral margin of the thorax dorsally. Average length 0.95 mm.

Second instar.—Color yellow. Eyes dull red. Antennae extending to hind margin of thorax. Dark markings more evident, those on vertex less irregular in shape and often in the form of two distinctly separated brownish-black lines; thoracic markings on pronotum consisting of two spots situated near hind margin, one on each side; those on mesonotum in a semi-curved line on each side following the lateral contours of the segment; those on metanotum two in number, shaped like an inverted comma and situated dorso-laterally, one on each side. Average length 1.2 mm.

Third instar.—Color yellow. Eyes dull white underlaid by red. Antennae extending to front margin of metathorax. Wing pads making their appearance. Dark markings in some specimens showing the beginning of disintegration from irregular lines into a series of spots. Average length 1.5 mm.

Fourth instar.—Color deeper yellow. Eyes more whitish. Antennae extending to mesothorax. Wing pads reaching the second abdominal segment. The brownish-black markings now consisting of four short narrow lines on the frontal margin of the vertex, their distance apart considerably less than their length and the outer one on each side not attaining the margin of the eye. Markings of the thorax appearing as spots arranged as follows: 2 near

posterior margin of pronotum, 1 one on each side; 10 on mesonotum, 5 on each side, 4 extending from the anterior to the posterior margins, and the fifth situated along the posterior margin one-quarter of its distance from the side; 6 on metanotum, 2 located along each side, 1 above the other, and 1 inward along the hind margin on each side one-quarter of the distance from the lateral margin. Average length 1.9 mm. (Fig. 9, A.)

Fifth instar.—Color as in previous stage. Eyes white. Antennae reaching hind margin of mesothorax. Wing pads extending to the third and sometimes the fourth abdominal segment. The black markings more prominent, the two posterior lateral spots on each side of mesonotum now being situated on the basal third of the front wing pad, one above the other, the two lateral spots on the metanotum on each side similarly located on the hind wing pads. Average length 2.46 mm.

THE ADULT

Descriptions of the typical red form, of the yellow form, and of the variety *dorsalis*, taken from McAtee (*29, p. 277–278*), follow.

Erythroneura obliqua var. *obliqua* (Say). * * * Ground color of scutellum and anterior upper surface pale opaque yellow, markings two orange-red vittae connivent on vertex, forming an inverted V-shaped mark common to vertex

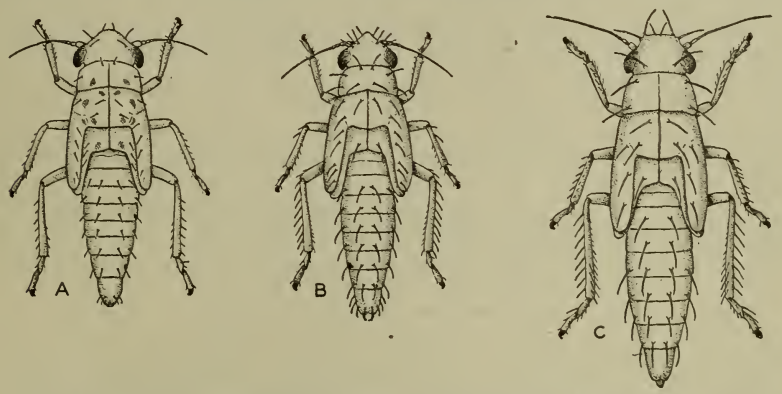

FIGURE 9.—Fourth-instar nymphs of apple leaf hoppers: A, *Erythroneura obliqua*, × 20; B, *E. maculata*, × 20; C, *Typhlocyba pomaria*, × 22

and pronotum; scutellum with median pale yellow opaque vitta, bordered by two narrow orange red lines, tip orange red. Tegmina whitish hyaline, bearing orange red markings as follows: Vitta on clavus interrupted except for dots near radial margin, then continued along that margin nearly to tip of clavus; a long vitta along third sector, curved at apex along part of base of fourth apical cell; narrow stripe along anterior half or more of costal margin; thread of color along first sector, and sometimes along cross-veins; apical cells slightly yellowish smoky; costal plaques greenish yellow. Ground color below pale yellow, stripe along pleura pale reddish; arcuate cross-band on lower surface of vertex and touches of color elsewhere on face, orange-yellow to red; fore tibiae washed with reddish; claws black.

[Length, one female, 3 mm.; other specimens, 2.6 to 3.1 mm.]

Erythroneura obliqua var. *obliqua* (Say), yellow form. Color pattern as in the red form, but with the color markings varying from yellow through light-greenish-yellow to pellucid or livid; tegmina more hyaline; costal plaques whitish usually obscured by the color markings.

[Length, one female, 2.8 mm.]

[*Erythroneura obliqua* var. *dorsalis* (Gillette), red form.] In its best development variety *dorsalis* has the head and pronotum, except narrow lateral margins and the scutellum and clavi, entirely covered by a broad continuous

red stripe; the corial vittae are unusually broadened, originate about middle of corium and are cut sharply off at cross-veins; apical cells dusky. The principal variations are that narrow slaty-drab vittae and edgings may mark the places where more extensive pale areas are present in variety *obliqua*, or the tegminal vittae may be well separated as in typical form; inner apical cells are quite black sometimes, continuing the dorsal stripe to apices of tegmina.

[Length, one female, 2.57 mm.]

THE RED-SPOTTED APPLE LEAF HOPPER [6]

HISTORY AND SYNONYMY

This leaf hopper was originally described by Gillette (*21, p. 764*) as a variety of the grape leaf hopper under the name of *Typhlocyba comes* var. *maculata*. Wirtner (*44, p. 227*), in 1904, reported this species from Pennsylvania, and Tucker (*38, p. 68*), in 1907, collected the insect in Kansas, but no mention was made of the host plants in either of these records. In 1920 Lawson (*25, p. 252*) redescribed the insect as a distinct species, *Erythroneura maculata* (Gill.), and he stated that the specific host plant was unknown at that time. During the same year McAtee (*29, p. 298*) redescribed Gillette's type specimen under the name *Erythroneura maculata* var. *maculata* (Gill.). This leaf hopper was reported as a pest of economic importance for the first time by Ball (*5*) in 1926, when he gave his observations on the life history of the insect on sycamore at Washington, D. C. A new species, *E. omani*, was described by Beamer (*7, p. 49–50*) in 1930, and specimens of the red-spotted apple leaf hopper treated in this bulletin have been identified as *omani*. The name *E. maculata* is retained for the species, however, in this bulletin.

DISTRIBUTION AND FOOD PLANTS

This insect, like *Erythroneura obliqua*, is evidently a native species. McAtee (*29, p. 289–299*) gives the following distribution records: District of Columbia, Maryland, Virginia, Tennessee, Georgia, Texas, Indiana, Missouri, Kansas, and Iowa. In a later publication McAtee (*30, p. 133*) adds the following States: New York, New Jersey, Massachusetts, Wisconsin, Colorado, and California. The writers have specimens of the species also from Illinois and Ohio.

The red-spotted apple leaf hopper resembles the original grape leaf hopper, *Erythroneura comes* (Say), so closely that it may be readily mistaken for the grape species. *E. maculata* confines its attack to apple among the host plants of economic importance, however, whereas *E. comes* is strictly a grape species.

The mention of sycamore as a host plant of this species by Ball (*5, p. 96*) is the only record found in literature of a food plant of this leaf hopper. At Bentonville, Ark., the insect has been found breeding on raspberry and elm to a limited extent, as well as on sycamore. Nevertheless, apple is the only host plant in the Ozarks upon which it is sufficiently abundant to be a pest.

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[6] *Erythroneura maculata* var. *maculata* (Gill.); order Hemiptera, family Cicadellidae, subfamily Eupteryginae.

DESCRIPTION OF THE STAGES OF ERYTHRONEURA MACULATA

THE EGG

The egg of *Erythroneura maculata* resembles that of *E. obliqua* so closely that no further description of this stage is necessary.

THE NYMPH

First instar.—Color pale white with a tinge of light yellow after feeding. Eyes deep red. Antennae about two-thirds length of body. Average length 0.9 mm.

Second instar.—General color white to pale yellow with tinge of deeper yellow in the median dorsal area of the body. Eyes dull red. Antennae extending to hind margin of metathorax or slightly beyond. Average length 1.2 mm.

Third instar.—General color as in previous instar. Eyes losing some of their color, becoming lighter. Antennae extending to metathorax. Wing pads beginning to appear. Average length 1.4 mm.

Fourth instar.—Color as in previous instar. Body more robust. Eyes dull white. Antennae extending to mesothorax. Wing pads reaching second abdominal segment. Average length 1.8 mm. (Fig. 9, B.)

Fifth instar.—The yellowish color more prominent than in previous instars. Eyes white. Antennae extending to mesothorax. Wing pads more prominent and attaining third abdominal segment. Average length 2.4 mm.

THE ADULT

Descriptions of the type specimen and the yellow form by McAtee (*29, p. 298*) are as follows:

Erythroneura maculata var. *maculata* Gillette. * * * Ground color of scutellum and anterior parts ivory, of tegmina yellowish hyaline: with the following scarlet markings; median vitta on vertex, discal and two lateral large spots, besides two faint ones near anterior margin, on pronotum, basal angles and apex of scutellum, three well-separated spots on clavus, a spot at base of corium, an oblique streak over front of costal plaque, spot between latter and clavus, three streaks along sectors just posterior to costal plaque, and a line on cross-veins extending slightly also on adjacent parts of sectors and apical veins; apical cells yellowish fumose, a dark dot in base of fourth. Undersurface and legs stramineous to yellowish.

[Length 2.64 mm.; other specimens 2.64 to 3.03 mm.]

Erythroneura maculata var. *maculata* Gillette yellow form. Like the preceding except that the color markings are of varying shades of (greenish to orange) yellow instead of red. This being a generally paler form the markings of scutellum and anterior parts often are merely translucent ground color.

[Length 3.03 mm.]

THE WHITE APPLE LEAF HOPPER[7]

HISTORICAL STATEMENT

The white apple leaf hopper has been confused with the rose leaf hopper, *T. rosae* (L), in American entomological literature. Published accounts of the rose leaf hopper as a pest of apple in the past may apply partially to the European species *rosae*, since this insect may occur on apple as well as on rose, but it is more likely that these

[7] *Typhlocyba pomaria* McAtee; order Hemiptera, family Cicadellidae, subfamily Eupteryginae.

references are to a native species, *T. pomaria*, which spends its entire life on apple. The original description of the apple species was given in 1926 under the name *Typhlocyba pomaria* by McAtee (*31*) to whom credit is due for the first differentiation of these two species.

Because of the confusion of the two species of Typhlocyba in the United States it is not possible to state exactly the distribution and food plants of the species. Previous accounts of the rose leaf hopper mention the rose and apple as the preferred food plants of *T. rosae*. It is probable that the common and preferred host plant of *T. rosae* is rose, while that of *T. pomaria* is apple. Likewise, both species will probably be found to occur in most of the apple districts of the United States, since the published literature on the confused *T. rosae* shows that it is generally distributed throughout this country.

T. pomaria occurs on apple at Bentonville, Ark., but no specimens of *T. rosae* have been collected in this locality. At West Chester, Pa., the senior author has seen first-generation nymphs of a white leaf hopper hatching from winter eggs on rose at the same time that white nymphs of the first generation of *T. pomaria* hatched from winter eggs on apple. It is very probable, therefore, that both *T. rosae* and *T. pomaria* occur in Pennsylvania.

DESCRIPTION OF THE STAGES OF TYPHLOCYBA POMARIA

THE EGG

The egg is elongate oval, slightly crescentic in form, almost circular in cross section, and blunt at both ends. It is semitransparent, but when ready to hatch it changes to a milky white, while the red eyes of the young nymph are visible through the smooth chorion. Average length 0.65 mm., width 0.19 mm.

THE NYMPH

First instar.—Color pale white changing to light yellow after feeding. Eyes dull red. Small spines present on dorsal side of the head, thorax, and abdomen; the latter with four spines to each segment arranged in two longitudinal rows on each side. Posterior margin of metathorax blunt. First two segments of antennae pale, remainder dusky. Average length 0.98 mm.

Second instar.—General color creamy white to light yellow. Eyes losing some of red color. Wing pads beginning to appear as lateral buds. Posterior margin of metathorax sharp in outline. First two segments of antennae yellow, remainder dusky. Average length 1.27 mm.

Third instar.—General color light yellow. Eyes dull white. Body more robust. Wing pads extending to hind margin of first abdominal segment. Spines darker and more prominent. Average length 1.55 mm.

Fourth instar.—General color light yellow. Eyes almost pearl white, with a brown central spot underneath. Wing pads extending to hind margin of the second abdominal segment. Spines very distinct. Average length 2.03 mm. (Fig. 9, C.)

Fifth instar.—General color as in previous instar. Eyes pearl white. Wing pads extending nearly to the hind margin of the fourth abdominal segment. Broader than in previous instar. Average length 2.85 mm.

THE ADULT

The description of the adult is taken from McAtee (*31*, *p. 29–30*).

Male. Head and thorax pale yellow, more or less tinged with orange to reddish on front of vertex; tegmina hyaline, the costa, commissure and sectors yellow, apical cells faintly dusky; underparts pale yellowish, the face more

or less tinged with orange to reddish, touches of this higher coloration elsewhere also on some specimens.

Hypopygium (fig. 59): Strongly distinguished by the falcate process forming the posterior border of the side of the 9th segment, which is heavily chitinized and black in color; as the correlation of this falcate process with the type of aedeagus here illustrated for this species has thus far been constant, it results that the species can be recognized from the superficial aspect of the hypopygium, the black tips of the falces being easily seen. Near the upper posterior border of the falx are several backwardly directed bristly hairs; similar but shorter hairs form a row on the outer clasper, and longer softer hairs spring from the under side of this clasper, from the lower border of the 9th segment near articulation of outer clasper, and from the end of the anal tube. Outer claspers as seen from below depressed interiorly so that together they enclose a long narrow sunken area, clasper as a whole narrowed on posterior third, the apices somewhat spatulate and divergent; seen from side the outer clasper is curved upward at the beginning of its posterior third, in almost a right angle, apex somewhat spatulate and recurved; inner clasper slender, outcurved apically (fig. 60); the aedeagus as seen from above (fig. 61) with a median and two lateral branches, the former considerably shorter than the latter, furcate at the tip, and reinforced along the lower surface by two longitudinal stripes extending nearly to the apex appearing as ribs on back of aedeagus as seen from above; lateral processes becoming very slender apically the terminal portion curved outward and then forward. Aedeagus measured along curve, fully twice as long as connective (fig. 62).

Female. Paler than male, general coloration straminеous, with little or no yellow, orange, or reddish washing; tip of ovipositor sheath black. Eighth sternite, moderately pointed medially and emarginate laterally (fig. 103).

Length, 3–3.5 mm.

This is the species that has most often been identified as *T. rosae* Linnaeus.

THE POTATO LEAF HOPPER [8]

SYSTEMATIC HISTORY

The potato leaf hopper was first described by Harris (*22, p. 186*) in 1841 as a pest of beans under the name *Tettigonia fabae.* This fact was brought out by Ball (*4, p. 598*), who examined the type specimen of Harris's *fabae.* LeBaron (*26*), in 1853, unaware of Harris's species, described the insect as *Tettigonia mali*, a pest of apple. This species has usually been referred to in literature, following LeBaron's description, as *mali* and placed in various genera. In 1862 Walsh (*41, p. 147–149*) erected the genera Empoasca and Chloroneura with the description of three new species under each genus. Among the insects thus described Ball (*4, p. 599*) considers *E. viridescens* Walsh, *E. consobrina* Walsh, and *C. malefica* Walsh as synonyms of *E. fabae* (Harris). The name given by Ball for this species has been followed by the writers.

The synonymy of *Empoasca fabae* (Harris) is as follows:

1841. *Tettigonia fabae* Harris (*22, p. 186*).
1853. *Tettigonia mali* LeBaron (*26, p. 330; 15, p. 174*).
1862. *Empoasca viridescens* Walsh (*41, p. 149; 42, p. 316*).
1862. *Empoasca consobrina* Walsh (*41, p. 149; 42, p. 316*).
1862. *Chloroneura malefica* Walsh (*41, p. 149; 42, p. 317*).
1879. *Typhlocyba photophila* Berg (*8, p. 273*).
1884. *Empoa albopicta* Forbes (*17, p. 181*).
1889. *Empoasca albopicta* (Forbes) Woodworth (*45, p. 211–214*).
1891. *Empoasca mali* (Le Baron) Gillette (*20, p. 104–106*).
1924. *Empoasca fabae* (Harris) Ball (*4, p. 598*).

[8] *Empoasca fabae* (Harris); order Hemiptera, family Cicadellidae, subfamily Eupteryginae.

ECONOMIC HISTORY

Forbes (*17*, *p. 181*), in 1884, referred to this insect as "the green apple leaf hopper." Published accounts of the insect under the name of "the apple leaf hopper" or "the currant leaf hopper" by Britton (*9*, *p. 216*), Bues (*10*, *p. 324*), and Garman (*18*, *p. 57*) have appeared in literature. Washburn (*43*), in 1908, published an account of the seasonal history and control of the insect as a nursery pest of apple. In 1918, Lathrop (*23*) published on the life history of this apple leaf hopper. An account of the insect as a pest of apple nursery stock by Ackerman (*1*) appeared in 1919.

The first reference to this leaf hopper as a potato pest was by Osborn (*33*, *p. 603*) in 1896, and Gibson (*19*, *p. 119*) in 1909 mentioned it as destructive to potatoes at Ottawa, Ontario. The relation of this insect to the hopperburn of potato was suggested by Ball (*3*, *p. 149*) in 1919, and he also proposed that the common name of the insect should be changed to the potato leaf hopper, because potato was its preferred host plant. Fenton and Hartzell (*14*) in 1923 and De Long (*13*) in 1928 published on the biology and control of this leaf hopper.

DISTRIBUTION

The potato leaf hopper is widely distributed throughout the United States. Judging from collected specimens and from notes and correspondence of the Bureau of Entomology, it is present in almost every State in the Union. It is found in greatest abundance throughout the eastern humid area of the Upper Austral Zone. In the Americas, outside of the United States, it has been reported from British Columbia, Nova Scotia, Ontario, Mexico, Porto Rico, and Argentina. There are no records to indicate that this species occurs in Europe.

FOOD PLANTS

E. fabae is a general feeder, and it is likely to be present on a number of food plants at any time during its active life. Ackerman (*1*, *p. 3*) lists a total of 46 food plants for the insect. Fenton and Hartzell (*14*, *p. 382*) give the favored food plants of the species, in the order of their preference, as follows: Potato, beans, clover, alfalfa, and beets. The species in some States is a pest of apple and Norway maple in nurseries.

In the Ozarks potato and apple, especially nonbearing trees, are injured by the first generation of the insect. Potatoes are usually matured, and sometimes harvested, before the second generation makes its appearance. The insect leaves apple also after the first generation is completed and disperses to late plantings of beans and to the more succulent weeds. This leaf hopper is most commonly injurious on beans in the Ozarks because successive plantings of this crop provide tender vegetation during most of the season.

DESCRIPTION OF THE STAGES OF EMPOASCA FABAE

The five nymphal instars and the adult are shown in Figure 4.

THE EGG

Egg elongate, subcylindrical, very delicate, slightly curved from end to end, somewhat rounded at both ends, but more so at the anterior end. When first

deposited it is rather transparent, but in a few days it changes to a pale yellow while a small white cap forms at the anterior end through which the red eyes of the immature nymph are perceptible. Average length 0.82 mm., width 0.25 mm.

THE NYMPH

First instar.—Pale white, changing to a light yellowish green after feeding. Eyes dull red. Small pale spines on the dorsal side of the head, thorax, and abdomen; the latter with four spines to each segment arranged in two longitudinal rows along each side, one spine situated dorso-laterally, the other ventro-laterally. Posterior margin of metathorax blunt. First two segments of antennae pale, the remainder dusky. Average length 1 mm.

Second instar.—General color light yellowish green. Eyes losing some of their red color. Posterior border of metathorax sharp in outline. First two segments of antennae light yellow, remainder dusky. Average length 1.30 mm.

Third instar—General color pale yellowish green. Eyes almost pearl white. Body more robust than in first two stages. Wing pads appearing as lateral buds extending to the hind margin of the first abdominal segment. Spines darker and more prominent. Average length 1.85 mm.

Fourth instar.—Head and thorax yellowish green; abdomen yellow. Eyes pearl white. Wing pads extending to hind margin of second abdominal segment. Spines prominent. Average length 2.1 mm.

Fifth instar.—Head and thorax pale green; abdomen yellow. Wing pads extending to, or nearly to, the hind margin of the fourth abdominal segment. First two antennal segments green, remainder dusky. Body broader than in previous instar. Average length 2.6 mm.

THE ADULT

General color pale green; face with a white median longitudinal line in older specimens but composed of a series of white spots in newly transformed individuals; median line extending from a point midway between the ocelli to a point half the distance to lower margin of clypeus; two short white diagonal bands on each side of median line, the lower one the smaller; a short white line, often merely two spots, beyond the diagonal and just above the antennae; a faint white line midway between the ocellus and eye. Antennae 1 mm. in length, arising near the lower frontal border of the eyes; clypeus one-third longer than broad; lorae narrow, not reaching the tips of clypeus, concave below eyes; genae almost as long and half as broad as clypeus, with one or two faint white spots. Vertex dark green, with a median white line, narrowest in middle, its length equal to distance between the ocelli; a white band on each side, dorso-lateral and diagonal to median line. Two ocelli present, marked by two white spots and situated on frontal margin of vertex, their distance apart equal to twice that from the eye to the ocellus; eyes dull white, reddish brown after death. Pronotum pale green, hind margin very pale, with eight white spots along the frontal margin, the last spot at each end small and often fused with the one next to it so as to form only six spots; mesonotum with two parallel white longitudinal lines centrally located and connected by a transverse one in the form of a letter "H," a faint white diagonal line present on each lateral margin; scutellum small with a large white triangular area in the center and a small spot on each side along the frontal margin. Abdominal segments yellowish green with transverse yellow stripes on their hind margins, anal segment dark green. Legs green, tarsi dusky at the tips. Sexual appendages ciliated in both sexes. Average length 3.12 mm.

THE GREEN APPLE LEAF HOPPER[9]

SYSTEMATIC HISTORY

According to Ball (*4, p. 597*) this species was originally described in 1862 by Walsh (*41*) as *Chloroneura maligna.* In 1898 Gillette (*21, p. 731*), apparently not recognizing Walsh's *maligna*, described

[9] *Empoasca maligna* (Walsh); order Hemiptera, family Cicadellidae, subfamily Eupteryginae.

the insect as a new species under the name *Empoasca unicolor*, which is the scientific name used in referring to this species by later writers. Ball (*4, p. 599*), in 1924, stated that the genus Chloroneura is a synonym of Emposaca,[10] and this species, therefore, takes the scientific name *Empoasca maligna* (Walsh). The writers have followed Ball's use of the scientific name.

ECONOMIC HISTORY AND FOOD PLANTS

This insect was called the malignant leaf hopper by Walsh in 1862 (*41*), because this was one of two species which were supposed to be the cause of fire blight on apple and pear. In 1909 Parrott (*35, p. 79*) mentions *Empoasca unicolor* as one of the three species of leaf hoppers occurring on apple in New York. Childs (*11, p. 4*), in 1918, listed this species as numerous in Oregon in a few isolated orchards but not widely distributed on apple. Lathrop (*23*) gave an account of the life history and habits of this leaf hopper on apple in 1918. Ball (*4, p. 597*), in 1924, published an article on this species in which he named the insect " the apple leaf hopper."

DISTRIBUTION

The green apple leaf hopper is probably a native species, and it appears to occur in most of the apple districts of the United States. Ball (*4, p. 597*) states that it is distributed from the Rocky Mountains to the Atlantic. Its occurrence on the Pacific coast is recorded by Childs (*11, p. 4*), in addition to the distribution given by Ball.

DESCRIPTION OF THE STAGES OF EMPOASCA MALIGNA

The description of the egg and nymph are by Lathrop (*23, p 193*), and the description of the adult is by Gillette (*21 p. 731*).

THE EGG

The egg is deposited in the bark of apple and was found to occur most abundantly in growth of the previous season. . . . The blisters and eggs resemble those of *E. rosae* but are slightly larger.

THE NYMPH

The nymph of this species, as with the preceding form [*Empoasca fabae*], deepens in color with age. The final instar is of a bright-green color, with the anterior portion of the vertex, the sides of the pronotum, the wing pads, and the last abdominal segment strongly tinged with yellow. A rather indefinite smoky spot is apparent on each side near the middle of the front margin of the mesonotum; a blackish spot occurs on each side of the posterior margin of the mesonotum, and another pair is placed in the same position on the metanotum. A stripe of dark green extends along the dorsal meson of the abdomen.

THE ADULT

Color varying from yellowish to greenish, without conspicuous markings, 3.5 mm. long.

Face yellow above, without markings, shading into green below, the length exceeding the breadth by about one-fifth, clypeus exceeding the lorae by about

[10] It is so in part, as pointed out by McAtee (*28*).

one-third its length, considerably constricted below its base and rather pointed. Vertex almost entirely yellow in some specimens but, in all, a median pale stripe and a pale or bluish blotch next each eye are more or less plainly visible. In some specimens there are also a pair of green dots a little before the middle of the vertex and rather near the median pale line. The vertex is not at all produced, its length is contained in the length of the pronotum almost exactly twice, and in the breadth of the head about 3.7 times. Pronotum slightly broader than the head, twice as wide as long, yellowish in color but more or less tinged with green posteriorly and, in most specimens, a small white spot can be seen on the middle of the anterior margin. Scutellum deeper yellow than the pronotum and with a pale or bluish blotch just before the apex, which, in some cases, extends forward to the margin of the pronotum. Elytra a golden green, the coloration stopping a little before the cross veins, the tips slightly smoky. Abdomen yellowish above and below, the last ventral segment of the female having two deep oblique notches or slits on the posterior margin inclosing a stout blunt tooth between them. Legs greenish yellow, tarsi blue.

REARING METHODS

In studying the life histories of the species of leaf hoppers under discussion, practically all data were obtained under outdoor conditions by rearing the insects in the insectary yard on small apple trees protected from outside infestation. Exceptions to this procedure were the records on oviposition by single pairs and some of the experiments on incubation, which were conducted in an open insectary on caged apple seedlings and grafts grown in 8 and 9 inch pots.

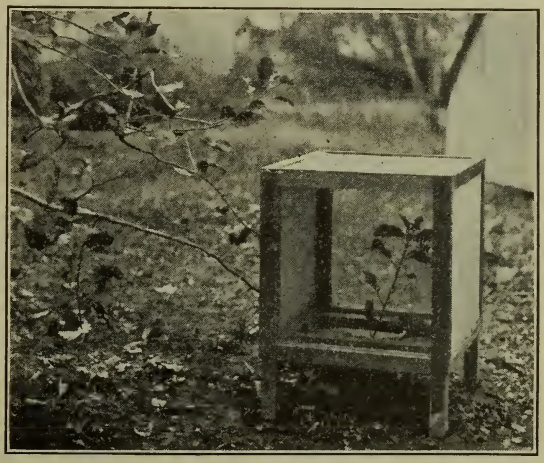

FIGURE 10.—Cube-shaped tree cage used for incubation and longevity records

Records on incubation and oviposition were obtained from counts of nymphs which emerged, since the eggs are concealed in the leaf tissue and the act of egg deposition can not be observed with accuracy.

Temperatures during the periods of development were taken from a thermograph kept in a standard United States Weather Bureau shelter placed among the trees in the insectary yard and from a thermograph in the insectary shelter. The instruments were checked daily with maximum and minimum thermometers and with an accurate centigrade thermometer. Mean daily temperatures were derived by 2-hour readings from the thermographs.

Cube-shaped cages (fig. 10) measuring 20 inches each way were used for obtaining records on incubation and on the longevity of adults. In each of these a branch of a young tree could be inclosed. These cages were designed to furnish, as nearly as possible, normal light and ventilation. The top and two opposite sides were covered with muslin, and the other two sides were of glass. The hand

could be put into the cage through a muslin sleeve in the bottom. Corner legs held the cages about 6 inches off the ground. Modification of this cage, by the addition of a sleeve in one of the muslin sides, made it possible to fasten the cage permanently over a seedling tree. When it was found desirable to cage apple twigs at some distance above the ground the cages were set on wooden frames which could be made any desired height.

Celluloid cylinder cages were found very satisfactory for obtaining records on oviposition and incubation. One type of cage (fig. 11) consisted of a cylinder 7 inches in diameter and 15 inches high. The lower 5 inches and the upper 2 inches of this were made of 30-mesh copper screen. The central section was of sheet celluloid which lapped over the wire screen about 1 inch at the top and bottom. The top was of muslin, but the lower end was open so that the cage could be set down over a small tree in an 8-inch pot.

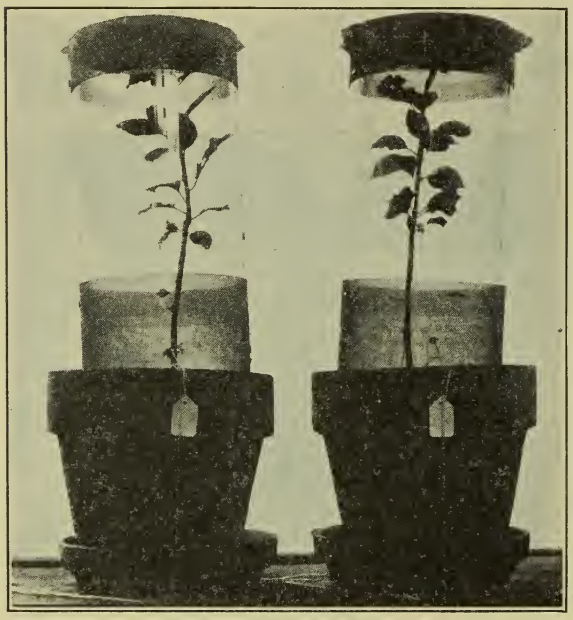

FIGURE 11.—Celluloid cylinder cages in position over potted apple trees in which life histories of single pairs of leaf hoppers were studied

These cages were put together over cylyndrical wooden forms, and the overlapping edges were so closely fastened that neither nymphs nor adults could possibly escape. They were made in several sizes, but the size just described proved very convenient, and it was found that the cages with a diameter of more than 8 inches were not sufficiently rigid for use with such small insects.

By confining a single pair of adults in a cage of this type it was possible to study the life history from the time of hatching until death, under practically outdoor conditions.

The presence of nymphs could be detected on the leaves through the celluloid sides and the beginning of the hatching period noted. Each day, then, after the daily emergence of nymphs was completed the cage was raised and the adults caught in glass vials. The nymphs were removed and counted, and the adults were immediately returned to the cage.

For incubation records, celluloid cylinder cages (fig. 12) were made with an open muslin sleeve sewed to the screen collars at each end. They could be placed over an apple twig either at the terminal end of the twig or along the middle. The muslin sleeve was tied with

string at one end, and the adults were put on the foliage through the other end, after which the sleeve at that end was also fastened with string. By shaking the adults from the foliage to the side of the cage they could be transferred, cage and all, daily to fresh apple twigs, and successive daily incubation records could be obtained with the same individuals.

The cages in which nymphs were reared to determine the exact time required for passing through the various nymphal stages were of two types, both of which were used throughout the entire study. One (fig. 13 at right) has been described previously by Ackerman (*1*, *p. 8*) as follows:

> A piece of thin sheet cork was cut about 2 inches square, in the center of which a 1-inch square hole was made. White muslin cloth was stretched tightly over one side of the cork and glued fast so as to cover the center hole. Heavy wadding cut to the shape of the cork, but leaving the center open, was glued to the other side. With the muslin side out, the cage was then placed over a newly hatched nymph on the lower surface of a leaf. A square of stiff cardboard of the same size as the cork was placed on the upper side of the leaf, and the cardboard, leaf, and cage were fastened together by paper clips. The young nymph within the cage received ventilation from both sides, through the porous wadding and through the muslin top. The leaf tissue was protected against injury by the cardboard on its upper surface and by the wadding on its lower surface.

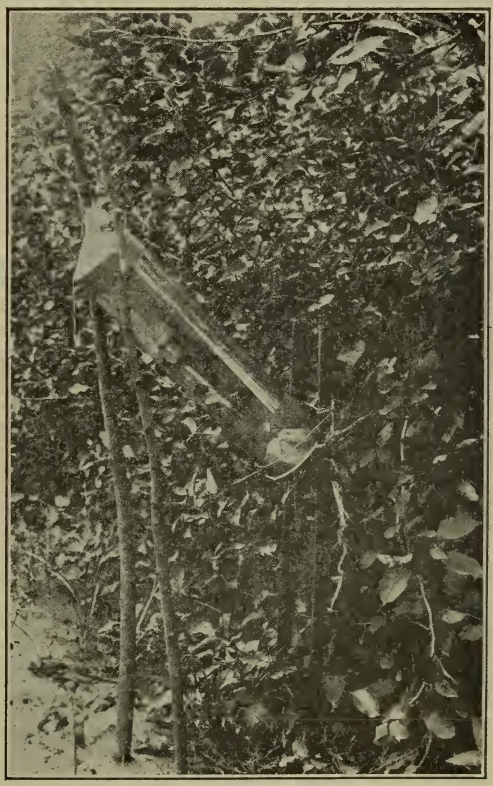

FIGURE 12.—Celluloid cylinder cage used for records on incubation

The other type of cage (fig. 13, at left) was made of a celluloid cylinder, about 4 inches long and 1½ inches in diameter, capped with muslin at one end, and on the other end fitted with a short muslin sleeve which could be slipped over a leaf and tied to the petiole. This cage had the advantage, particularly with the older instars, of permitting observations to be made without removing it. It had the disadvantage, on account of its size, of being subject to a greater wind hazard, and on several occasions a large percentage of the leaves to which these cages were attached were broken off. Very small nymphs were frequently lost in these cages, probably because they fell off the leaves upon which they were feeding and could not get back.

The material for life-history studies was collected at the beginning of the season, and all leaf hoppers used in the studies of the later generations were descendents of this material. The three species which overwintered as adults were collected and caged as soon as they became active on apple foliage in the spring. It was necessary to start several cages of reserve material in the early spring to insure a plentiful supply of insects of known ancestry. The two species which wintered in the egg stage were reared from nymphs hatching in the early spring.

In studying the life history of single pairs in confinement plans were made to carry on line-breeding work. It was necessary to alter these plans during the course of the work, however, when it became evident that males and females which hatched on the same day did not always produce offspring. Several cage experiments of single pairs on potted plants were failures during the season's work because mating and reproduction did not take place. For this reason, records were not available of the progeny of the first and last individuals of each generation in all cases, so the exact extremes of the generations were not determined. Nevertheless, enough experiments proved successful for sufficient evidence to be secured on the range of the developmental periods of the different stages throughout the season.

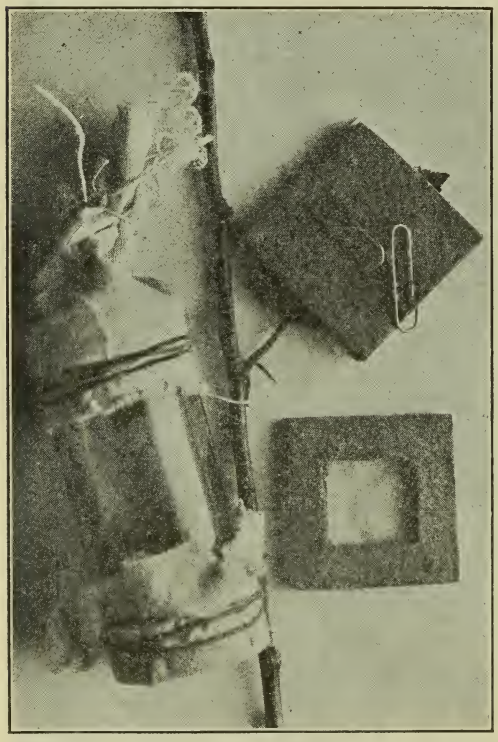

FIGURE 13.—Types of cages used for rearing nymphs: At left, a celluloid sleeve cage inclosing an apple leaf; at right, a cork-sheet cage, open, and in position over leaf

Determinations of the limits of the generations were based on life histories of single pairs in cages, on reserve material used for some of the data on duration of nymphal stages, and on the progeny of the longevity cages. All this material was of known ancestry, so there was no chance of any confusion in the generation studies.

COMPARISON OF LIFE HISTORIES

The life-history studies cover rearing records for individuals of three generations of *Erythroneura obliqua*, *E. maculata*, and *Empoasca fabae*, two generations of *Typhlocyba pomaria*, and one generation of *Empoasca maligna*. The first three species hibernate as adults and the last two in the egg stage.

LONGEVITY

Records of adult longevity of the different species are given in Table 1. The data on the overwintered generation of the three species in the table cover the period only from the time of appearance of the leaf hoppers on apple in the spring. It will be noted from the table that longevity of adults of the first two species is considerably greater than that of the other three. *Erythroneura obliqua* and *E. maculata* adults live and feed during a very long period.

TABLE 1.—*Longevity records of the adults of five species of apple leaf hoppers, showing the range and average period for the sexes and generations, Bentonville, Ark., 1925*

Species	Generation	Longevity		Sex	
		Range	Average period	Male	Female
		Days	*Days*	*Number*	*Number*
Erythroneura obliqua	Overwintered	[1]6–101	40.5		68
	do	[1]6– 80	34.1	41	
	First	23–193	69.2		30
	do	22–191	52.0	30	
	Second	14–168	45.0		55
	do	9–151	47.0	56	
Erythroneura maculata	Overwintered	[1]3– 90	50.1		99
	do	[1]4– 88	46.4	42	
	First	17–196	61.6		58
	do	15–194	50.7	79	
	Second	15–156	66.5		48
	do	13–151	48.7	33	
Empoasca fabae	Overwintered [1]	6– 85	29.2		98
	do	6– 62	24.3	25	
	First	3– 80	18.0		117
	do	4– 43	12.8	43	
	Second	5– 55	23.5		49
	do	4– 33	15.4	22	
Typhlocyba pomaria	First	5– 41	29.1		79
	do	6– 35	18.8	154	
	Second	8– 64	24.5		105
	do	10– 66	34.2	39	
Empoasca maligna	First	12– 42	27.5		75
	do	5– 32	22.3	70	

[1] Counting only from time of appearance on apple.

OVIPOSITION

Data on oviposition by single pairs of *Erythroneura obliqua* and *E. maculata* appear in Table 2. Records on oviposition by females of the other three species were rather fragmentary.

TABLE 2.—*Comparison of oviposition by segregated pairs of Erythroneura obliqua and E. maculata, Bentonville, Ark., 1925*

Generation	Species	Pairs	Preoviposition period		Oviposition period		Postoviposition period		Oviposition rate		
			Range	Average	Range	Average	Range	Average	Range	Average	
										Total	Per day
		Number	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Number*	*Number*	*Number*
Overwintered	*Obliqua*	9			24–41	36.4	0–25	12.6	22–117	74.8	1.9
	Maculata	8			25–41	36.5	0–24	9.8	29–114	64.6	1.7
First	*Obliqua*	3	7–8	7.7	21–35	28.3	0	0	39–95	65.3	2.5
	Maculata	5	5–8	6.7	9–44	28.3	1–61	23.3	15–172	89.0	2.7
Second	*Obliqua*	4	9–11	10.0	8–26	17.5	0–21	6.8	13–71	33.5	1.9
	Maculata	5	8–17	11.0	5–16	11.4	2–6	5.4	6–27	20.2	2.3

In the case of *Empoasca fabae* much difficulty was encountered in securing records because of the severe injury caused to plants by the continued confinement of adults. Considerable variation occured in the duration of the oviposition period and in the number of eggs deposited by this species. For 11 individual pairs, the period ranged from 3 to 61 days, while the laying rate ranged from 0.4 to 2.6 eggs daily. DeLong (*13*) reports an average preoviposition period for 90 pairs of *E. fabae* of 6.2 days during one season and during a second season, on the basis of observation of 50 pairs of leaf hoppers, of 6.1 days. He also reported a high egg record of 226 eggs deposited during 47 days, an average rate of 4.8 eggs daily.

Several experiments on oviposition by first-brood adults of *T. pomaria* were a failure because of the loss of foliage in which the eggs were deposited. The incubation period of summer eggs of this species was very prolonged, and the leaves on the plants became infected with mildew before hatching occurred. Exact records on oviposition were not secured because of the difficulty of observing actual deposition of eggs and because of the length and irregularity of the incubation period. The mean period from transformation to mating for six pairs of first-brood adults in 1928 was 6.2 days, and the range in total number of eggs developing was from 42 to 114, with a mean of 76.7. No data were secured on the number of winter eggs deposited.

Oviposition by *E. maligna* occurs during May and June. The eggs are placed under the bark in young wood, and hatching takes place the following spring. The females of five pairs, in 1925, deposited an average of 32.3 winter eggs each.

INCUBATION PERIOD

The duration of the incubation period for the five species is shown in Table 3. Within a species temperature appears to be the only factor which influences the duration of the incubation period. The records cover eggs for all generations, but only in the case of *Empoasca fabae* were a representative number of eggs observed. Even for this species data were not obtained covering the very early-season eggs which were laid during periods of very low temperature.

TABLE 3.—*Duration of incubation period of five species of apple leaf hoppers, showing the range, average period, and mean temperature, Bentonville, Ark.*

Species	Year	Range	Average period	Mean temperature	Obersvations
		Days	*Days*	*°F.*	*Number*
Erythroneura obliqua	1925	10–19	16. 0±0. 03	74. 6±0. 12	1, 049
Erythroneura maculata	1925	11–19	14. 9± . 04	73. 9± . 12	929
Empoasca fabae	1928	6–15	8. 1± . 01	75. 7± . 02	5, 582
Typhlocyba pomaria (winter eggs)	1925	201–213	205		86
Typhlocyba pomaria (summer eggs)	1925	63–86	74. 6		281
Empoasca maligna	1925	323–338	330		147

NYMPHAL DEVELOPMENT

The duration of the nymphal instars and the total nymphal period appear in Tables 4 and 5, respectively. Observations on molting

were made daily, usually by 10 a. m. It was found that virtually all the nymphs molted in the morning, with the exceptions of nymphs reared very early in the season, when low temperatures prevailed. In these cases molting took place later in the day. The temperatures were taken from thermographs kept in Weather Bureau shelters among the trees where the work was conducted. The daily mean temperature from 10 a. m. to 10 a. m. was derived by 2-hour readings from the thermograph. Maximum and minimum thermometers as well as a centigrade thermometer registering to 0.1° were used to check the accuracy of the thermograph.

Under comparable varying temperatures under outdoor conditions, it was apparent that *Empoasca fabae* nymphs of the several instars completed development more rapidly than those of any of the other species.

TABLE 4.—*Duration of nymphal instars of five species of apple leaf hoppers, showing the range, average period, and mean temperature, Bentonville, Ark.*

Instar	Range	Average period	Mean temperature	Observations
ERYTHRONEURA OBLIQUA, 1925				
	Days	*Days*	*°F*	*Number*
First	3–7	4. 5±0. 03	74. 5±0. 20	359
Second	3–7	3. 5± . 04	75. 6± . 20	347
Third	2–7	3. 4± . 03	76. 4± . 16	330
Fourth	2–7	3. 7± . 04	76. 7± . 13	324
Fifth	3–9	5. 8± . 05	76. 4± . 13	315
EMPOASCA FABAE, 1925				
First	1–7	3. 3±0. 05	70. 4±0. 31	319
Second	1–7	2. 7± . 04	73. 3± . 32	278
Third	1–6	2. 6± . 05	75. 0± . 32	216
Fourth	1–7	2. 7± . 06	76. 7± . 31	181
Fifth	1–9	4. 0± . 08	77. 7± . 27	167
EMPOASCA MALIGNA, 1925				
First	3–5	4. 4±0. 03	71. 1±0. 16	114
Second	2–9	3. 7± . 13	71. 1± . 41	109
Third	2–9	5. 4± . 14	67. 0± . 45	102
Fourth	5–11	8. 7± . 12	57. 9± . 29	87
Fifth	7–12	9. 2± . 10	64. 8± . 13	86

Instar	Range	Average period	Mean temperature	Observations
ERYTHRONEURA MACULATA, 1925				
	Days	*Days*	*°F.*	*Number*
First	2–7	4. 6±0. 05	74. 0±0. 23	326
Second	2–7	3. 4± . 04	75. 9± . 20	321
Third	2–6	3. 2± . 03	77. 5± . 13	311
Fourth	2–6	3. 5± . 03	77. 5± . 07	303
Fifth	3–8	5. 4± . 04	77. 4± . 07	293
TYPHLOCYBA POMARIA, 1928				
First	2–9	4. 5±0. 06	70. 0±0. 32	451
Second	2–6	3. 4± . 03	71. 8± . 22	434
Third	2–6	3. 5± . 03	71. 3± . 22	422
Fourth	2–6	3. 8± . 03	72. 0± . 18	410
Fifth	4–10	5. 9± . 04	70. 7± . 16	380
EMPOASCA MALIGNA, 1929				
First	8–12	9. 4±0. 04	56. 8±0. 05	132
Second	5–10	7. 6± . 05	57. 7± . 09	129
Third	4–10	7. 7± . 09	58. 8± . 18	129
Fourth	4–10	6. 6± . 07	63. 0± . 14	125
Fifth	6–12	10. 4± . 08	63. 1± . 14	118

TABLE 5.—*Duration of the nymphal period of five species of apple leaf hoppers, showing the range, average period, and mean temperature, Bentonville, Ark.*

Species	Year	Range	Average period	Mean temperature	Observations
		Days	*Days*	*°F.*	*Number*
Erythroneura obliqua	1925	14–29	20. 7±0. 11	75. 0±0. 12	306
Erythroneura maculata	1925	14–28	19. 8± . 08	75. 5± . 10	293
Empoasca fabae	1925	9–30	14. 8± . 24	74. 3± . 28	167
Empoasca maligna	1925	24–33	29. 3± . 19	62. 6± . 05	74
Typhlocyba pomaria	1925	15–28	19. 8± . 15	72. 3± . 33	154
Typhlocyba pomaria	1928	15–31	21. 1± . 16	70. 5± . 10	380

COMPARISON OF SEASONAL HISTORIES AND HABITS

ERYTHRONEURA OBLIQUA AND E. MACULATA

The oblique-striped and the red-spotted apple leaf hoppers, like other species of the genus Erythroneura, hibernate in the adult state, under dead leaves, vegetation, or any trash accumulated around an orchard. During the warm days of late winter and early spring the adults become active and may fly up in swarms if the leaves under the trees are disturbed. They disperse to apple trees just as soon as the young leaves are formed and feed on the foliage several weeks before eggs are laid.

Eggs of both species are deposited in the under surfaces of leaves beneath the lower epidermis. Both nymphs and adults feed on the under sides of the leaves. They prefer mature leaves on the lower branches of trees.

Mating by overwintered adults takes place shortly after their appearance on apple. Mating previous to the dispersal to apple is rather rare, although one pair was taken in coitu on March 11 and another pair on March 22 while still hidden under leaves in an orchard. Copulation by adults of the first and second generations usually occurs from 5 to 15 days after transformation to the adult stage.

Most of the overwintered adults die by the end of May, after the first nymphs have appeared, although a few stragglers live as late as July, when first-generation adults are present in large numbers. The first-generation nymphs are most abundant in early June. First-generation adults live for a long period, a few individuals remaining alive until the latter part of December. After the middle of July first-generation and second-generation adults may be present on apple at the same time. In September, and later, adults of the first, second, and third generations may occur together in the field. The overlapping of the adult periods of the different generations results from the presence of early and late hatching individuals and the long life of the adults. The overlapping of the generations, however, is not marked until late in the season. The characteristic feature of the life history of these two species is the extreme longevity of adults of all generations.

Late nymphs of the first generation may be found on apple at the time the earlier individuals of the second generation appear. Nymphs of the second generation are seen from the first of July until the last of August, and they are present in greatest numbers about August 1. Third-generation nymphs hatch from the middle of August until late in September. Considerable overlapping of the second-generation and third-generation nymphs occurs in August and September.

These two leaf hoppers have two complete generations and part of a third generation at Bentonville, Ark. Second-generation adults which transform before the middle of August produce a partial third generation. The daily oviposition rate of these second-generation females is just as regular as in the case of females of the earlier generations, but the period of laying is shortened, owing to the

approach of cold weather, so the total number of eggs deposited is smaller. Second-generation adults which mated and produced a third generation showed no tendency to hibernate, as they all died soon after oviposition ceased.

Second-generation adults which transformed after the middle of August did not mate or produce any progeny in cages. The life of these second-generation females which did not reach sexual maturity during the fall was very much prolonged. It is presumed that these late-transforming second-generation adults overwinter.

The third-generation nymphs transform to adults during September and October, and after feeding for a short period these adults seek hibernation quarters late in October.

Figure 14 shows the periods during which the adults and immature stages of the various generations of the two species of Erythroneura were present in the orchards in 1925.

TYPHLOCYBA POMARIA

The white apple leaf hopper has two generations each year in Arkansas, with no overlapping of the active stages of the two generations. Adults of the first or spring generation all die before the appearance of nymphs of the second or late summer generation.

The insect hibernates in the egg stage. The winter eggs are laid singly under the bark of the young wood during the early fall, and they appear on the twigs as tiny raised blisters, usually concentric in form. Eggs for the second generation are deposited in May and June in the leaf tissues of the undersides of the lower leaves. The creamy white nymphs and adults of both generations feed on the lower sides of the older leaves during their entire life. Their attack is confined almost entirely to the lower parts of the trees.

The eggs that are to overwinter are deposited in the latter part of September and during October. These eggs hatch during a period of approximately two weeks about the middle of April of the following year. The majority of the eggs hatch within a period of about four days.

At Bentonville, in 1925, first-generation nymphs were found on apple from April 10 to May 28, and the adults of this generation were present from April 24 to June 12. The first summer eggs were deposited about May 5, and hatching occurred from July 22 to September 15. From June 12 to July 22 no active stages of the insect were present either in cages or in the field. Second-generation nymphs or adults were present on apple from July 22 to November 2.

Both generations of the white apple leaf hopper have very long egg stages and a comparatively short nymphal and adult stage. In more northern fruit districts the summer egg stage is considerably shorter than in Arkansas. At West Chester, Pa., for instance, the incubation period for summer-brood eggs ranged in 1916 from 23 to 27 days (*1*, *p. 25*), and either nymphs or adults were present on apple throughout the summer months. A diagram of the generations of this species is given in Figure 14, in which the solid lines represent actual cage records, and the hatched lines indicate records determined by careful field observations.

EMPOASCA FABAE

The potato leaf hoppers pass the winter as adults which become active in the spring about the middle of April. They feed first on

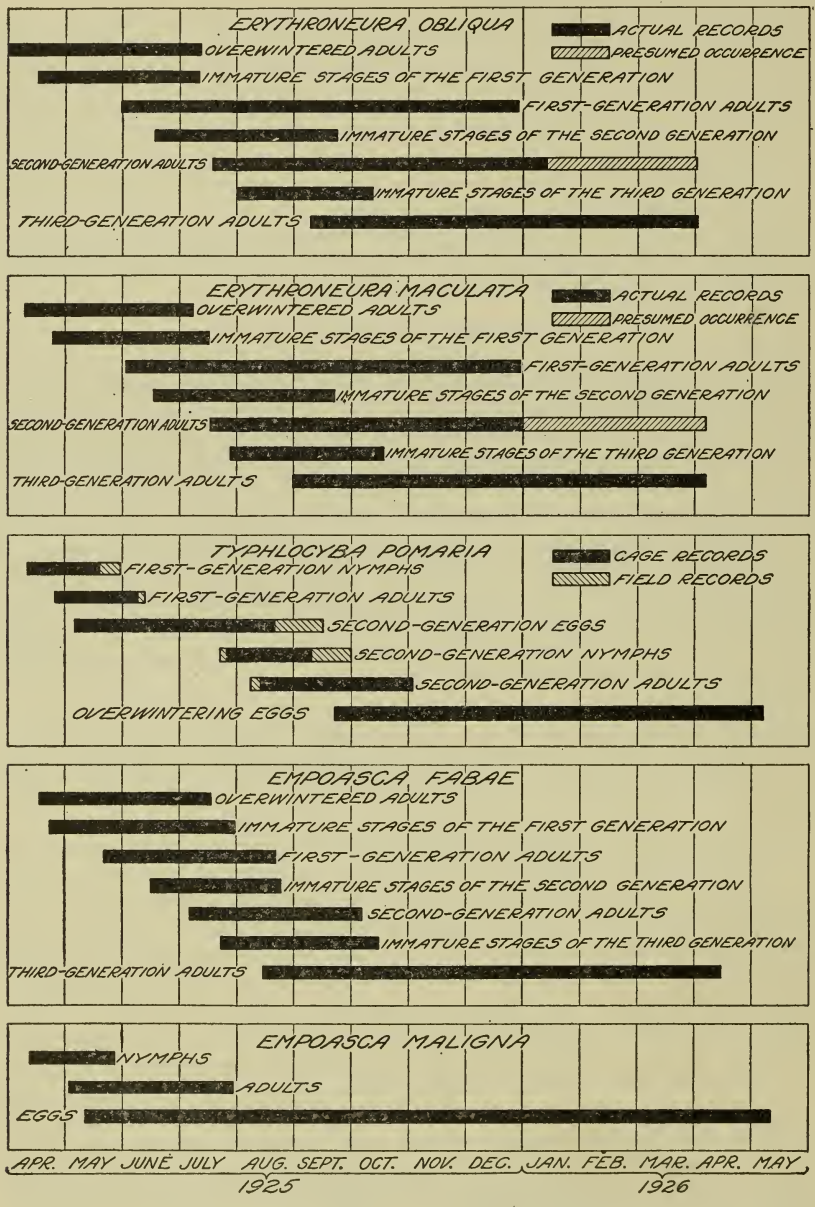

FIGURE 14.—Comparative representation of the seasonal histories of the five species of apple leaf hoppers at Bentonville, Ark., in 1925, showing the extension of the overwintering stages into 1926

grasses and tender weeds such as curly dock, and a few days later they may be found on apple in scant numbers. The insects do not

become abundant on their preferred host plants, however, until the "spring flight" takes place. At this time the adults migrate in large numbers within the period of less than a day to apple and other hosts, and egg laying commences at once. Mating apparently occurs prior to this migration, as females are sexually mature when they arrive on their favored host plants.

At Bentonville, in 1925, the spring flight occurred on the afternoon of May 8. It is probable that a change in temperature and humidity as well as sexual maturity had some influence in timing this migration. The morning of May 8 was cool, with a gentle rain falling. In the afternoon the rain stopped, and warm humid weather prevailed. For several hours during this time the adults were observed migrating to apple and beans in large numbers.

Fenton and Hartzell (*14, p. 393*) noted a similar spring migration by this insect to potato at Ames, Iowa, on June 6, 1919, on June 27, 1920, and on June 17, 1921.

The eggs of this species are deposited in the veins and petioles of the new leaves. The nymphs and adults are very active. They feed on the undersides of the tender terminal leaves, but after the completion of the first generation on apple the terminal foliage usually becomes too woody to suit the insect, and large numbers of adults disperse to more tender host plants.

Three generations of *E. fabae* were reared at Bentonville in 1925. Fenton and Hartzell (*14, p. 393–394*) show that there are two generations on potato at Ames, Iowa, the first generation of nymphs appearing in 1920 from late June to the first part of August. At Bentonville, on the other hand, in 1925 the first nymphs of the season emerged on May 1, and the majority of the first-generation nymphs transformed to adults by the middle of June, though some were present for a month longer.

Nymphs of the second generation hatch from the last of June to the first week in August, and they are most abundant during the first two weeks in July. Third-generation nymphs hatch during August and September. Nymphs of only the first generation appear in sufficient numbers on apple to cause injury. Nymphs of the later generations are found in greater abundance on more succulent host plants than apple.

Migration of this species from cultivated plants to tender weeds takes place in the late summer. This migration occurs over a longer period than the spring flight. During the late summer migration the adults may be found in abundance swarming about electric lights, especially on nights when the temperature and humidity are very high. There have been occasional reports of swarms of *E. fabae* appearing at lights on evenings in late summer at various localities in the country. Swarming undoubtedly occurs during the time of dispersal from field crops to weeds and other vegetation. At Bentonville the swarming of adults at lights on a night in late summer has been observed during several seasons.

Late in the summer the adults of the last generation disperse from the economic host plants to feed on more succulent weeds before they finally disappear. Even though diligent search has been made in all kinds of cover where other leaf hoppers hibernate, no speci-

men of this species has been collected in hibernation in the Ozarks. The insects remain in hibernation for a period of from five to six months.

In cages the life cycle of the first generation averaged 53 days, that of the second generation 29 days, and that of the last generation, which includes hibernating adults, about eight to nine months.

A diagram of the occurrence of the adults and immature stages of the generations of *E. fabae* appears in Figure 14.

EMPOASCA MALIGNA

There is one generation a year of the green apple leaf hopper with hibernation taking place in the egg stage. At Bentonville the eggs are deposited in May and June, and the remainder of the growing season and the winter are spent in this stage. The eggs are laid under the bark of young apple twigs, being found most abundant in the second and third year's growth. They resemble the eggs of the white apple leaf hopper, but they are slightly larger than the latter.

The nymphs which hatch from the overwintered eggs in April are always found on the undersides of the older leaves of the trees. This species produces the same type of injury to foliage as that caused by all other species except the potato leaf hopper. The green apple leaf hopper, however, unlike the other species, confines its attack largely to the outer border of the leaves. Nymphs are present on apple for a period of only about six weeks during the year, from about the middle of April until the last of May.

Adults of *E. maligna* are present in the lower parts of trees for a period of about two months from the first of May to the first of July, though a few stragglers may be found throughout the month of July. The majority of the adults, however, die by the middle of June. The longevity of the species in captivity averaged less than a month. From July until the following April no active stages of this leaf hopper have been found on apple or on any other plant in the Ozarks. In western New York, on the other hand, Lathrop (*23, p. 191*) reports that adults of this leaf hopper are present on apple from the first week of July until late fall, when eggs are deposited in the bark.

A diagram of the seasonal history of *E. maligna* is shown in Figure 14.

NATURAL ENEMIES

The natural enemies of apple leaf hoppers seldom occur in sufficient abundance to hold these insects in check. Among predators, spiders, mites, pentatomids, and assassin bugs have been observed attacking nymphs and adults occasionally. Chrysopid and coccinellid larvae and numerous species of birds also attack leaf hoppers.

The most important predator on any of the leaf-hopper species is the glossy-winged soldier bug, *Hyaliodes vitripennis* Say. Both nymphs and adults of this predator attack nymphs of *Typhlocyba pomaria* in large numbers, especially late in the summer. *Triphleps insidiosus* Say is a rather common predator of *Empoasca fabae* and *E. maligna.*

Hymenopterous parasites of eggs and adults are important enemies of some species. *Anagrus epos* Girault and *A. armatus* var. *nigriventris* Girault, parasites of the winter egg of the white apple leaf hopper, were abundant at West Chester, Pa., in 1916. These parasites have been reared from winter eggs of this leaf hopper collected in a number of States, and they very likely occur in Arkansas.

Aphelopus albopictus Ashm. has been observed in the act of ovipositing in the abdomen of nymphs of the potato leaf hopper at West Chester, Pa.

The most effective parasite of the leaf hoppers at Bentonville, Ark., in 1925 was *Aphelopus comesi* Fenton. This dryinid parasite was sufficiently abundant to reduce materially the numbers of second-brood adults of the red-spotted apple leaf hopper. Dryinids were also found on the oblique-striped leaf hopper, but this species was rather free of parasites as compared with the red-spotted leaf hopper. Parasitism of the potato leaf hopper and of the white apple leaf hopper by dryinids was very rare in Arkansas.

CONTROL MEASURES

Experiments for the control of the oblique-striped and red-spotted apple leaf hoppers, the two species of Erythroneura, were conducted at Bentonville, Ark., during the seasons of 1920, 1921, 1924, and 1927. The seasonal history of these two species is so nearly alike that a single spray treatment is effective against the nymphs of both species.

All sprays were applied with power sprayers which maintained a pressure of 225 to 250 pounds. Spray rods with double angle nozzles were used; and the spray solution was directed, as far as possible, against the underside of the leaves where the nymphs feed. The insecticides used in the sprays for control of leaf hoppers were combined with one of the regular scheduled summer sprays in which Bordeaux mixture and lead arsenate were used to control fungous diseases and the codling moth. An exception to this procedure occurred in the experiments of 1921, when no lead arsenate was necessary, because of the failure of the crop that season.

For the dust applications a power dusting machine was used, and the dusting was done in the evening on calm days.

In the experiments of 1920 and 1921 counts were made of the number of nymphs alive on 800 leaves from each plat after the spray solution had had sufficient time to act. The percentage of nymphs killed by the sprays was then figured. The scoring of results in 1924 and 1927 was done by counts of a number of leaves from each plat showing the number of live nymphs per leaf surviving the treatments.

No experiments were attempted for the control of the white apple leaf hopper, the potato leaf hopper, or the green apple leaf hopper. These species, especially the last two, are not usually of sufficient importance to justify a spray treatment. When the white apple leaf hopper occasionally becomes abundant enough to require a spray for its control, the insecticides which will control the species of Erythroneura may be used effectively. If directed against first-brood nymphs of the white apple leaf hopper, however, the spray should

be applied from four to six weeks earlier than for the two species of Erythroneura, because of the difference in time of the nymphal infestation.

Spraying experiments for the control of first-brood nymphs of *Erythroneura obliqua* and *E. maculata* were conducted at Bentonville in 1920 on a block of Ben Davis trees. The trees selected for spraying were very large and had been pruned in such a manner that the lower limbs touched the ground. This method of pruning produced a dense shade under the trees which afforded ideal conditions for a heavy leaf hopper infestation.

The spray application was made on June 15, when the majority of the nymphs had attained the third stage of development. Nicotine sulphate, at a strength of 1–1,600 added to Bordeaux-lead arsenate, and the same mixture with the addition of laundry soap, one-half pound to 50 gallons, were tested. The counts of nymphs showed 92 per cent killed with the nicotine-Bordeaux mixture and 95 per cent where laundry soap was added. The average number of nymphs per leaf was 0.07 on the first plat, 0.04 on the second plat, and 0.89 on unsprayed trees. Observations were made of the sprayed and unsprayed trees after the appearance of the second and third broods. While leaf hoppers were abundant on the unsprayed trees throughout the season, they were not numerous enough on the sprayed blocks to cause any damage. Since the adults migrate very slowly reinfestation of unsprayed trees was not of much consequence.

Tests were carried on against second-brood nymphs in 1921 on July 27 when the earliest nymphs of this generation had reached the fourth instar. The following materials were tested: On plat 1, nicotine sulphate (40 per cent nicotine), at 1–1,600, rosin fish-oil soap 1–50, and Bordeaux mixture, 3–4–50; on plat 2, rosin fish-oil soap 1–50 plus 3–4–50 Bordeaux mixture; on plat 3, Bordeaux mixture 3–4–50; and on plat 4, Bordeaux mixture 3–10–50. Counts of surviving nymphs in the above experiments showed 97 per cent killed on plat 1, 89 per cent on plat 2, 24 per cent on plat 3, and 39 per cent on plat 4. The unsprayed trees showed an infestation of 0.8 nymph per leaf.

Bordeaux mixture is generally recommended as a very effective insecticide for the control of *Empoasca fabae* on potato. Against the two species of Erythroneura on apple it proved to be of little value.

In 1924 spraying and dusting experiments were conducted in four different orchards at Bentonville. Three experiments were for control of the first brood and one for the second brood of the Erythroneura. The infestations on unsprayed trees in these orchards ranged from an average of 0.51 to 0.95 nymph per leaf for the first brood, and averaged 1.79 per leaf for the second brood. The insecticides included nicotine sulphate, 1–1,600, with Bordeaux mixture; 2 per cent lubricating-oil emulsion with Bordeaux mixture; and nicotine-hydrated lime dusts containing, 1, 1½, and 2 per cent nicotine. In these experiments the only effective control of nymphs was obtained with the nicotine-Bordeaux combination. The 2 per cent lubricating-oil emulsion proved slightly better than the nicotine dust mixture,

but none of these materials at the dosages tested was of sufficient value to justify further trial.

An experiment with a high dosage of nicotine sulphate was conducted against the summer broods of nymphs on August 15, 1927, in an effort to secure a thorough clean-up of leaf hoppers with a single spray application. Nicotine sulphate at 1–800 was used with a 4–4–50 Bordeaux mixture on a large block of heavily infested trees. Counts of nymphs were made prior to the application on a check plat and on the plat intended for spraying. There were 1.41 nymphs per leaf on the check plat and 1.47 nymphs per leaf on the demonstration plat. Twenty-four hours after spraying there was a reduction on the sprayed plat to 0.035 nymph per leaf. Counts made on thousands of leaves of the sprayed and unsprayed plats on August 24 showed 0.036 nymph per leaf on the sprayed trees, as compared with 1.90 nymphs per leaf on unsprayed trees. During the interval between August 15 and August 24 large numbers of nymphs hatched on unsprayed trees from eggs already deposited. On the sprayed plat such eggs evidently failed to hatch, since there was no increase in the population of nymphs as revealed by the counts. The nicotine, therefore, appeared to be effective in preventing the hatching of eggs for a period of several days following the spray application. The sprayed plat remained relatively free from leaf hoppers during the remainder of the season.

METHOD AND TIMES OF APPLICATION

Adult leaf hoppers can not be controlled by sprays, as the winged insects fly away from the spray solution before it comes in contact with them.

For effective control of these insects sprays must be applied when the insects are in the nymphal stages. The correct time to apply the sprays is during the period when a large number of nymphs are in the third stage of development. At this time practically all the eggs will have hatched, and the earliest maturing nymphs will have begun to transform to adults. In the Ozarks for first-brood nymphs this period is usually from June 10 to 20. A spray for second-brood nymphs should be applied about August 1 in a normal year.

Since the leaf hoppers feed on the underside of the leaves the spray solution must, of necessity, be directed upward in order to hit the nymphs; and a rather high pressure that will force the mist of spray up through the leaves is desirable.

Ordinarily it is not necessary to make a special spray application for leaf hoppers. Insecticides used for the control of these insects can be combined with one of the regular summer apple sprays. Treatment for first-brood nymphs would come at the time of the first regular spray for bitter rot, whereas treatment intended for the second brood could be combined with one of the late summer sprays.

A single spray application, preferably against first-brood nymphs, is usually sufficient to insure good control. Reinfestation of sprayed trees and subsequent damage by adults from outside is virtually negligible, as these leaf hoppers migrate very little. In seasons when first-brood nymphs are relatively scarce a spray should be applied for second-brood nymphs if they become abundant.

SUMMARY

The injury to the apple caused by leaf hoppers is not so evident as that caused by other insects that attack the fruit itself. The crop is reduced and the trees weakened on account of the injury to the foliage caused by the feeding of the leaf hoppers.

This bulletin gives an account of experimental studies on the five species of leaf hopper that attack the apple in the Ozark Mountain region of Arkansas. The data regarding the life and seasonal histories are for this particular district, the investigations being centered at Bentonville.

The five species discussed, with the common names properly used to identify them in ordinary parlance, are *Erythroneura obliqua*, the oblique-striped apple leaf hopper; *E. maculata*, the red-spotted apple leaf hopper; *Typhlocyba pomaria*, the white apple leaf hopper; *Empoasca fabae*, the potato leaf hopper; and *E. maligna*, the green apple leaf hopper. Other species infesting apples are listed but are not discussed at any length.

The two species of Erythroneura are the most injurious in the Ozark district as they are less affected by dry, hot weather. None are of primary importance.

The injury caused by these leaf hoppers results from the extraction of plant juices from the leaves. The potato leaf hopper attacks the terminal leaves and new growth, but the other species feed almost entirely on the older leaves.

Characters and keys for distinguishing the adults and nymphs and technical descriptions of each of the five species are given, and also notes on the history and synonymy and on the distribution and recorded food plants.

The experimental work was carried out under outdoor conditions by the use of cages fastened over parts of growing trees, or set over small potted seedlings, and by means of a special type of cell in which nymphs could be confined on a portion of a single leaf.

The two species of Erythroneura have almost identical habits, seasonal histories, and life histories. Both have two complete generations and a partial third generation annually. They pass the winter as adults and emerge from hibernation in early spring when the leaves begin to expand. Nymphs of the first generation hatch from early May until late June.

The adult life of all generations is much prolonged. Overwintered adults may live until July after the heaviest emergence of first-generation adults is over. Adults of the first, second, and third generations may be present on apple at the same time in September. The first and second generations overlap slightly, and the second and third generations overlap more extensively. The third generation is not so large as the earlier generations. It is produced by second-generation adults which transform during the earlier part of the emergence period. Late-transforming second-generation adults produce no progeny in the fall, and some of them probably hibernate. Third-generation adults feed for only a short period before seeking hibernation quarters.

The time required for incubation of the two species, *E. obliqua* and *E. maculata*, for all generations averages about 16 and 15 days,

respectively. The duration of the total nymphal period averages about 21 and 20 days. The total life cycle of the first two generations averages about 55 days. The life cycle of the last generation, which includes hibernation, covers from eight to nine months.

The white apple leaf hopper has two generations a year. The insect hibernates in the egg stage, the eggs being deposited under the bark of the young wood. The eggs hatch in April, and the majority of the first-generation nymphs emerge within a period of less than a week. The nymphs of the first generation infest apple from early April until late May. First-generation adults are present in the field from the last of April until the middle of June. No active stages of this species are seen for a period of about six weeks in June and July. Second-generation eggs, which are deposited in the leaves during May and June, hatch from the last of July to the middle of September. Adults of the second generation occur on apple from about the middle of August to the first of November. Deposition of winter eggs takes place in September and October. The incubation period of winter eggs is about six months, and that of the summer eggs exceeds two months. This species differs from the species of Erythroneura by spending a long time in the egg stage and a relatively short time in the adult stage.

Three generations of the potato leaf hopper were reared in 1925. The insects pass the winter as adults which emerge from hibernation in April. Migration to apple occurs at the time of "spring flight" early in May when the females are sexually mature. First-generation nymphs, which are the only ones that cause injury, appear on apple from the first of May to the middle of July.

The adult life of this species, except of overwintering individuals, is much shorter than the adult life of the two species of Erythroneura. The longevity of adults in captivity averages less than a month. The overwintered adults remain in hibernation for about six months.

There is considerable variation in the length of the incubation period. In cool weather eggs of the first generation may require as long as 18 days to hatch, whereas eggs of the summer generations may hatch in 6 days during hot weather. The duration of the nymphal period is similarly influenced by temperature. Nymphs hatching in early spring may require 30 days to reach the adult stages, whereas nymphs hatching from eggs in midsummer may require as little as 9 days to transform to adults.

The green apple leaf hopper has one complete generation each year. Winter is passed in the egg stage. The eggs are deposited in May and June beneath the outer bark of the young apple twigs and hatch in April of the following year. The nymphs feed on the lower leaves from the middle of April to the last of May. Adults are present on apple in abundant numbers during May and June. No active stages of this leaf hopper are encountered from the last of July until the following April. From 24 to 33 days are required to complete nymphal development. The average duration of the life of adults is a little less than a month.

Natural enemies are seldom of importance in the control of leaf hoppers. Experiments were conducted for the control, by spraying and dusting, of the two most injurious species, the oblique-striped

and the red-spotted apple leaf hoppers. The other three species, as a rule, are not sufficiently injurious to require control.

Leaf hoppers may be controlled by a contact spray applied before the nymphs transform to the adult stage. Experiments with nicotine sulphate at dosages as weak as 1–1,600 showed good commercial control. The addition of 1 pound of rosin fish-oil soap to each 50 gallons of spray solution made the treatment slightly more effective.

A 2 per cent lubricating-oil emulsion and fresh nicotine-hydrated lime dusts (containing up to 2 per cent of actual nicotine) were found to be less satisfactory than the sprays of nicotine sulphate. Bordeaux mixture, either a 3–4–50 or a 3–10–50 dilution, when used alone was ineffective against the two species of Erythroneura.

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